plausibly corrected, the observations of Maskelyne, treated by the method of comparison-stars, would give good instrumental results. No uncertainty, such as is produced by wearing of centre-work of the quadrant, attaches to Piazzi's or Pond's observations.

The correction of the refractions would be no very great work.

On the whole, we could wish that the able author of this paper could be induced to give to it all the completeness which existing materials can enable him to give. G. B. A.

On the Forms of Lenses proper for the Negative Eye-pieces of Telescopes. By G. B. Airy, Esq., Astronomer Royal.

In the *Monthly Notices* for June and November last, there are discussions on the forms of lenses proper for the Negative Eye-piece. Perhaps I shall not do wrong in stating to the Society that as long ago as the year 1827 I made a most elaborate investigation of the properties of Eye-pieces as depending on the curvatures of their surfaces. The paper is entitled "On the Spherical Aberration of the Eye-pieces of Telescopes," and is printed in the *Transactions of the Cambridge Philosophical Society*, vol. iii. This paper had been preceded by one "On the Chromatic Aberration of the Eye-pieces of Telescopes," from which I had been able to infer the proportions of the focal lengths and intervals of the lenses, which (independently of their curvatures) destroy colour at the sides of the field, using but one kind of glass; and had selected some of these as examples to which the formulæ for Spherical Aberration were to be applied. One of these is the Huyghenian Eye-piece, with the following very common proportions:—Focal length of first lens or field-glass = 3 M; focal length of second lens or eye-glass = M; interval between the two lenses = 2 M.

The principal results as applying to the cases before us are the following:—

First, as regards Distortion.

I must refer to page 15 of the Memoir for the general formula; but I may quote the following special results:—

(*a.*) It is possible to destroy Distortion entirely, but not by the use of common forms (equi-convex or plano-convex).

(*b.*) The most favourable combination of common lenses is,—the first, equi-convex; the second, plano-convex, with its convex side toward the first lens, or with its plane side next the eye.

Second, as regards Indistinctness at the edge of the field.

From the general formulæ in page 35 it appears that it is

impossible in any eye-piece whatever, in which the lenses are all convex, to secure distinctness in the approach to the edge of the field, except, in some cases, by movement of the eye-piece; and the problem always is to diminish the Indistinctness as much as possible. For this purpose, in the Huyghenian eye-piece,

(*c.*) The different points of the image may be made distinct by a little sliding of the eye-piece, by a form very nearly the same as the following:

(*d.*) The best form is, for the field-glass, a meniscus, with convex side towards the object-glass, and radii as 4 : 11; and for the eye-glass a convex lens, the mere convex side towards the field-glass, and radii as 1 : 6. The constants by which the indistinctness in the two dimensions is expressed are $\frac{\cdot 95}{126}$ and $\frac{\cdot 61}{126}$.

(*e.*) The best combination of common lenses is, two plano-convex-lenses, the plane sides of both towards the eye. The constants of indistinctness then are $\frac{133}{126}$ and $\frac{175}{126}$.

(*f.*) For a single lens to produce the same power, the smallest values of constants of indistinctness would be $\frac{196}{126}$ and $\frac{476}{126}$.

The following rule, though not strictly accurate, will be found sufficiently accurate to give a very good practical determination of the curvatures of all eye-piece lenses in all cases. Trace the course of an excentric pencil through the eye-piece. Consider separately the convergences, &c. of the axis of the pencil with regard to the axis of the telescope, and that of the rays of the pencil with regard to the axis of the pencil. When both these convergences fall on one side (as in the Huyghenian field-glass) the lens ought to be meniscus. When they are at equal distances on opposite sides, the lens ought to be equi-convex. When the convergence of either is much nearer (the other being on the opposite side), the side of the lens next it ought to be plane.

1862, *December* 10.

At the November Meeting the Astronomer Royal gave an interesting *vivâ voce* account of some investigations which have been recently made to improve our knowledge on the Measures of the Earth and of the Heavens.*

The first part of the Astronomer Royal's Address was

* I am indebted for this article to J. N. Lockyer, Esq., Fellow of the Society, who has kindly undertaken to supply reports of *vivâ voce* communications at the Meetings.—Ed.

illustrated by a map of Europe, on which had been inserted, by hand, the principal lines of triangulation of the countries already surveyed, and also the positions of several towns in Russia which had been obtained after the manner of a ship at sea. A glance at this map rendered evident the fact that the triangulation from the Danube to the North Cape on the North, and from the middle of Russia to Valentia Island on the West, left little to be desired.

Referring to the first labours of the French in the last century, and those of the French, Russians, and Swedes in the present century for the measures of different *Arcs of Meridian*, the Astronomer Royal observed that Russia has taken the lead in the geodetical operations at present in question—the measurement of an *Arc of Parallel.*

This arc, extending from Valentia on the West to the town of Orsk, situated in the extreme East of European Russia, and in nearly the same latitude as Valentia, comprises nearly seventy degrees of longitude, and is, as remarked by the Astronomer Royal, perhaps the longest one that will ever be measured by man.

It was pointed out, by means of the map, that this project of the elder Struve's, which was warmly taken up by the different Governments, by no means required the measurement of the entire arc: the existing triangulation, extending (as before remarked) from Valentia to a point pretty well advanced, would only require linking together where gaps existed, and extending eastward to Orsk.

To derive the measure of the Earth from these operations, it was first necessary to find, by some lineal measure, the *length of this arc;* in other words, to find the *distance in yards* (our standard measurement) between Valentia and Orsk; and, secondly, *the difference of the local times* at the two stations.

First, as to the length of the arc. The British part of it required little attention, as (thanks to the admirable work of the Ordnance Surveyors and subsequent investigation) the actual distance from Valentia to Dover is certainly known to within a few yards. Unfortunately the distance from Dover to Paris (equally well known) will not serve us, Paris being too far south. It became necessary, therefore, to effect a junction with the continental triangulation at some more northerly point; and this has been admirably effected, during the present year, by Sir H. James.

The whole distance from Valentia to some station well advanced is by this time computed, while the triangulation itself is fast approaching Orsk.

Secondly, as to the differences of local time at Valentia and Orsk. This, in an arc of such magnitude, can only be obtained from the differences of local times at intermediate stations in the arc; as, for instance, between Valentia and

Greenwich, Greenwich and Brussels, &c.; and in these determinations, as suggested by the illustrious projector of the operations, railways and telegraphs must be freely taken advantage of.

The difference of local times at Valentia and Greenwich was, as is well known, the subject of elaborate inquiry, some years ago, when several transmissions of chronometers were undertaken between the two places. The results obtained on this occasion have recently been confirmed in a remarkable manner, a complete electric circuit between the two places having been placed at the disposal of the Astronomer Royal by Sir Charles Bright. The difference of times obtained by the electric current (which, it may be stated *en passant*, took one-tenth of a second to traverse the 800 miles of wire) *agreed exactly* with that obtained from the chronometric expedition.

The second part of the Address related to the dimensions of the Solar System.

The recent researches into the velocity of light by means of the turning mirror—an instrument which, as used by M. Foucault, renders this velocity, inconceivable though it be, measurable by a cabinet experiment—and the parallax observations of *Mars*, which have been made during the autumn of this year in both hemispheres, were alluded to by the Astronomer Royal as affecting the determination of the Sun's distance, the unit of all measures of the Heavens.

The smaller velocity of light announced by M. Foucault was shown to necessitate a decrement of the Sun's distance, the two being connected by aberration; for as the umbrella of him who is caught in a shower inclines to meet the rain at a certain angle which depends upon the relative velocity of the rain-drops and the rate at which he is walking, so does the telescope point in advance of the star at a certain angle dependent upon the relative velocities of the light which enters it and the Earth which carries it.

This angle shows that the Earth travels (speaking in round numbers) 10,000 times more slowly than light. If, therefore, it is established that the received velocity of light must be diminished, the diameter of the Earth's orbit, which satisfies the received velocity, must be decreased in the same proportion.

The Sun's parallax, $8''\cdot5776$, deduced from the transits of *Venus* in 1761 and 1769, has also been called in question by M. Le Verrier, on other considerations; and the extreme doubtfulness of some of the most important observations of the transit of 1769 renders the success of those of the planet *Mars* doubly desirable; and although, by the latter method, the Sun's distance is only *indirectly* obtained (that of *Mars* resulting *directly* from the observations), the distances are bound together by a proportion which, as remarked by the

Astronomer Royal, was accurately known in the times of Copernicus and Tycho as at present.

There is reason to hope that the attempt of the present year will be attended with success. A fair number of eastern and western observations for the independent determinations have been obtained at Greenwich, and more are expected from Madras and Williamstown; and the meridian observations of Polar Distance (which require the co-operation of northern and southern observers) have been undertaken with vigour at all the Observatories of both hemispheres.

The Astronomer Royal also exhibited an original drawing of the fringes of light formed on a wall immediately before the disappearance of the Sun in the Total Eclipse of 1861, Dec. 31, prepared by a French officer, M. Poulain, Capitaine du Génie, at Goree.

In the accounts of the Eclipse of 1842 collected by M. Arago, and in those of the observers of later eclipses, it has been stated that in the last seconds before total obscuration there is a strange quivering of light upon the ground, &c., like the flitting of small shadows. The Astronomer Royal, in returning from his observing-station in Spain after the Total Eclipse of 1860, July 18, was accompanied in one journey by our Medallist, M. Goldschmidt (an excellent linguist), and by a Spanish gentleman who had observed the eclipse without instruments. This gentleman had been much struck by the sight of the flitting shadows; but, in the conversation which the Astronomer Royal held with him through the interpretation of M. Goldschmidt, it did not appear that the observations were made with such accuracy as to give useful information on the phenomenon.

On the occasion of the Total Eclipse of 1861, Dec. 31, M. Poulain, Capitaine du Génie in the French army, found himself at Goree, with the charge of observing the eclipse if possible; but without telescope or other instruments of the slightest accuracy. With great judgment, he applied himself to make the best use in his power of the means at hand. Meteorological observations of several classes were made with care, and recorded in a most orderly form; on these, however, the Astronomer Royal did not then insist, but proceeded to the depiction of the fringes, which M. Poulain had very carefully observed. The Sun was shining on a vertical white wall directed from east to west, and on this wall, a very short time before the totality (*un instant avant l'occultation*), the fringes were seen; and they were subsequently drawn by M. Poulain in their exact size (*en vrai grandeur*) on the sheet then exhibited. The only account of them given in the detailed record

is, "On voit des franges noires se dessiner sur le mur qui borde notre terrasse." The drawing exhibits five bands; three white, and two dusky-dark, each 4 inches broad; and their form seems to imply that in the longitudinal direction their length was considerable, and that in the lateral direction the repetition was more frequent. Their inclination to the vertical is about 45°; the right-hand end, referred to the hand of a person who is looking at the wall with his back to the Sun, being the lower.

At the Astronomer Royal's request, Mr. Hind was so good as to calculate the position of that point of the Sun's disk which was the last to disappear. It was at 31° from the Sun's vertex towards the east, or towards the left hand of an observer whose face was turned to the Sun. On comparing this with the position of the fringes, as depicted by M. Poulain, and referring the latter roughly to the direction of the Sun's rays, it appears that we may state, with as great accuracy as the observation permits, that the length of the fringes was in the same plane as the tangent to the disks of the Sun and Moon at the place of last disappearance.

The first impression from these appearances is, that they are diffraction-fringes; but the possibility of this explanation would seem to be destroyed by the consideration that any diffraction-fringes must travel with a linear velocity equal to the Moon's linear velocity, and must therefore be totally invisible. The phenomenon is one which deserves the careful attention of observers and optical philosophers. Meantime we may congratulate ourselves that we have for the first time a representation of this singular appearance aspiring to the character of reasonable accuracy. G. B. A.

Extract of a Letter from Herr A. Auwers to the Astronomer Royal, dated 5, Gartenstrasse, Gotha, 1861, December 1. —(Translation.)

Perhaps it is not uninteresting to you to know the result of researches on Parallaxes [of Stars] which I have carried out during the last two years at Königsberg. It is known that Struve, from observations with the Pulkowa Refractor for the parallel of 61 *Cygni*, has obtained a much larger value than Bessel had found with the Königsberg Heliometer, namely, 0″·5107 ± 0″·0282, instead of 0″·366 ± 0″·012. For that reason, I have effected a new determination with the Heliometer, in which I have made use of two comparison-stars different from those used by Bessel, which permit the application of the principle of differences in the most direct manner possible.